**Topic 1: Forests as safety nets**

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## SUMMARY

Capoeira or forest-fallow vegetation is an integral component of smallholder slash-and-burn systems in Eastern Amazonia. It plays a role, both in terms of environmental and socio-economic sustainability and serves as a safety net for farmers in numerous ways. Yet, with increasingly shortening fallow periods its potential declines. The paper describes, quantifies and speculates about potential safety net functions of the system's forest-fallow component and their improvements. These functions derive partly from the potential to directly utilize capoeira products like wood, charcoal or fruits. They also derive from the vegetation's ability to generate organic matter and to recycle nutrients for use by farmers' crops. Additional benefits are obtained from maintained biodiversity and the potential for forest regeneration. New developments suggest that through fire-free land management technologies and new policies and institutional arrangements, which offer remuneration for environmental services, the safety net functions could be improved.

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## INTRODUCTION

The current discussion on the management of tropical rainforests concentrates to a large extent on the analysis of determinants of deforestation in forest margin areas (ANDERSEN et al. 2002, ANGELSEN and KAIMOWITZ 2001, ANGELSEN and KAIMOWITZ 1999, VOSTI 2000). This discussion seems to be related to the increasing international concern for environmental issues, primarily climate, and the growing interest in biodiversity (BROWN and SCHRECKENBERG 1998). Less emphasis is put on former rainforest areas that have been utilized for long and where primary forest has largely been replaced by secondary vegetation. Yet, these areas could provide useful insights into development pathways and factors and offer indications on economic and environmental sustainability (HURTIENNE 1998).

Theories and concepts of sustainable development highlight the importance of a multi-dimensional (ecological, economic, social), evolutionary approach to economic development and environmental sustainability (MULDER and VAN DEN BERGH 1999, HOLLING 2000). Land-use systems, for example, constantly adapt depending on a multitude of biophysical, human, economic, and institutional factors. In addition, technological and policy change impact on land-use systems and stimulate the substitution of production factors (land, labor or capital). These changes can lead to positive or negative outcomes in terms of economic growth, the distribution of wealth, and the environment. Certain land-use systems, which developed under specific conditions, are less sustainable[4] while others are more sustainable. A system's ability to buffer shocks and to serve as a safety net plays an important role to secure sustainability.

This paper aims to describe, quantify and speculate about the safety net functions of the forest-fallow component of a smallholder land use system, which developed in the Eastern Amazon region. The system holds no primary forests, but uses secondary fallow vegetation (called *capoeira*) as an integral component. The paper takes an interdisciplinary perspective and reports on socio-economic and natural science related research results that explain the characteristics of the system. To account for evolutionary processes we understand the system to be constantly exposed to change through endogenous and exogenous factors and draw on existing time series data where possible.

## AIM AND SCOPE OF THE PAPER

### Objectives and Hypotheses

The overall objectives of the paper are (1) to review direct and indirect safety net functions of the forest-fallow component of the smallholder land-use system in terms of their contributions to smallholder's livelihoods and (2) to discuss the potential impact of technological and institutional innovations that foster these functions.

[4] In new frontier areas, for example, the high turn over of land holdings is caused by a focus on returns to labor and capital, rather than land, which is considered abundant. This poses a particular threat to the environment and triggers further incursion into primary forest areas (RICHARD, 1996).

More specifically the study

- Investigates the direct contribution of *capoeira* products to smallholder's livelihoods,
- Values the contribution of the *capoeira* to supply plant nutrients and to improve soil properties, thus guaranteeing its long-term sustainability,
- Assesses benefits for smallholders that arise from the possibility for forest regeneration, maintained biodiversity, and environmental markets,
- Evaluates the impact of technical, policy and institutional innovations for the system in terms of safety net functions, and
- Lastly discusses policy implications of the findings.

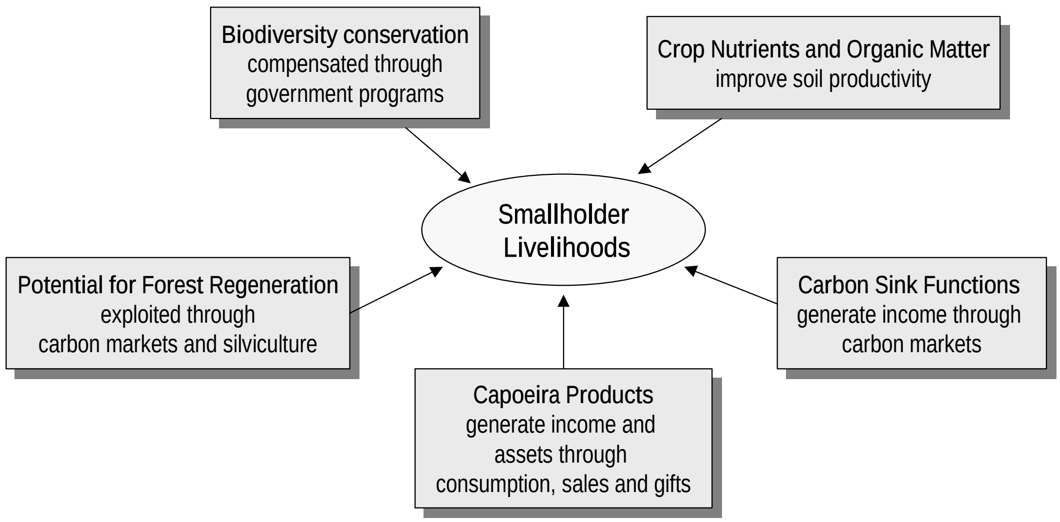
These objectives translate into the following hypotheses:

- The forest-based fallow system provides short-term direct and long-term indirect safety net functions to smallholders, but these declined over time;
- The contributions to livelihoods and safety net functions that evolve from the extraction of fallow products and from the utilization of biophysical and biochemical processes can be improved through technical and institutional innovations.

## Conceptual Framework

Conceptually the paper is based on the assumption that the different components of the forest-fallow form a safety net that smallholders can utilize. These components include *capoeira* products that can directly be transformed into income as well as functions like the nutrient pump function of the secondary vegetation that moves up nutrients from deeper soil layers for use by farmers crops, or the potential for forest regeneration that could offer benefits at a later stage. These safety net functions can be utilized indirectly and they involve a more or less extended time lag (Figure 1). We further assert that through technical and institutional innovations the functions of the forest-fallow can be strengthened and thereby contribute to stabilize the system.

**Figure 1. Contributions of forest-fallows to smallholder livelihoods**




## Methodological Tools and Data

The paper reviews findings of a ten-year-old multidisciplinary research project on the smallholder land-use system in the Eastern Amazon in light of the forest-fallow component's safety net functions. It thereby makes use of socio-economic surveys carried out more recently and results received from agronomic experiments and ecological field studies. Besides, we draw on secondary information for the study region, primarily derived from the Brazilian Geographical and Statistical Information Service (IBGE).

# THE SMALLHOLDER FOREST-BASED FALLOW SYSTEM

## The Evolution of the System

About hundred-and-fifty years ago, a region called the Bragantina[5], located east of Belém (Pará state), was gradually settled by smallholders. One of the major purposes of the initial settlement was the supply of staple food and fiber for the growing urban population of Belém. Hence, a semi-commercial system developed with emphasis on the production of cassava, beans, rice, maize and cotton, which still serves as the basis for smallholder livelihoods[6]. Farmers were usually allocated a plot of 25 hectare for which they received

[5] The Bragantina region covers an area of about 10 000 square kilometre and today comprises a population of about 500 000 people. Our definition of the Bragantina region includes the microregion Bragantina plus the municipalities of Castanhal and and Santa Isabel do Pará. Sixty-five percent of the population is classified as urban, and is located in four major centres (Castanhal, Bragança, Capanema, and Igarapé-Açu) of up to about 100 000 people (IBGE, 2001). The rural population includes about 20 000 smallholder households.

[6] Today the production of cotton and rice almost disappeared.

provisional title deeds. On the basis of family labor, they cultivated an area of about two to five hectares annually, leaving the rest as fallow.

The settlement of smallholders was supported by government through the establishment of infrastructure. This included the development of rural centers, and the construction of a railway line that connected Belém with the town of Bragança (located about 230 km east of Belém). With the expansion of the road network the railway was closed in 1966.

Since the 1960s the system gradually changed. With increasing population pressure and demand for land, farms were sold or split up among different descendants. This situation also led to decreasing fallow periods and increasing intensification. In the late 1960s black pepper, was introduced to smallholders, and later became an important source of income for the region (SOUSA FILHO 2003). The production of black pepper was supported by government credit programs, but extreme price fluctuations of up to 500% in the period 1983 to 1998 (E D & F MAN SPICES 2000) and production declines due to diseases led to a reduction of areas planted to black pepper, following its peak in the early 1980s (IBGE: PRODUÇÃO AGRÍCOLA MUNICIPAL). At the same time a market for another cash crop, passion fruit, developed. Again credit programs (FNO[7]) supported farmers, but pests and diseases presently reduce yields and as a result passion fruit areas are now declining substantially (IBGE: Produção Agrícola Municipal). In addition, some smallholders produced cattle but this is not a major enterprise. Despite growing concentration on commercial crops, smallholder or family agriculture is still predominant in the region (Table 1) and traditional crops (cassava, beans, and maize) continue to form the backbone of the smallholder system.

**Table 1. Selected parameters for the Bargantina region, 1980 to 1995**

| | 1980 | 1985 | 1995/96 |
|---|---|---|---|
| Population | 345 718 | 417 990 | 458 271 |
| Number of farms | 26 825 | 25 017 | 20 005 |
| Proportion of smallholders (< 50 ha) | 91. 4% | 91. 6% | 89. 4% |
| Proportion of smallholders (< 100 ha) | 96. 9% | 96. 6% | 94. 6% |
| Short Fallow (ha) [1] | 321 909 | 309 320 | 236 279 |
| Long Fallow (ha) [2] | 112 000 | 91 138 | 50 301 |
| Land use (ha) | 164 347 | 235 244 | 174 663 |
| Annual crops (ha) | 62 310 | 55 164 | 38 893 |
| Permanent crops (ha) | 19 125 | 19 676 | 20 819 |
| Pastures (ha) | 82 912 | 160 404 | 114 951 |

No Agricultural Census was conducted in 1990. Some loss of capoeira and agricultural land could be attributed to settlements and road building

[1] defined as " terras produtivas nao utilizadas" and "matas e florestas naturais" according to census

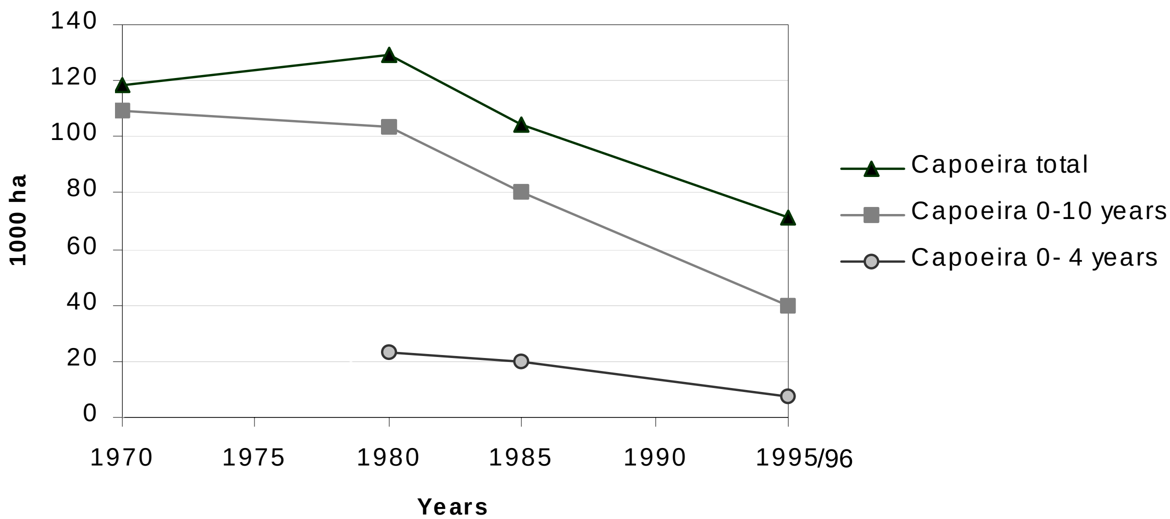
[2] defined as "lavouras temporáries em descanso" according to census

Source: IBGE 1991, IBGE 1993, IBGE 1998, IBGE 2001

[7] Fundo Constitucional de Financiamento do Norte

The colonization of the Braganina region had tremendous implications on its forest cover. Until 1955 most primary forest, apart from minor spots along rivers and on inaccessible terrain, was converted into agricultural land or fallow[8] (SOUSA FILHO 2003). Fallow includes secondary vegetation of different ages ranging from one to twenty five years, whereby the floristic composition changes over time. Figure 2 shows the sharp decline of *capoeira* (by 45%) in the period 1980 to 1995 in the three central municipalities of the Bragantina. This corresponds to a nineteen percent loss of *capoeira* on farm land (Figure 3).

**Figure 2. *Capoeira* area of different age in selected Municipalities (Capanema, Castanhal and Igarapé-Açu) in the Bragantina region, 1970-1985**

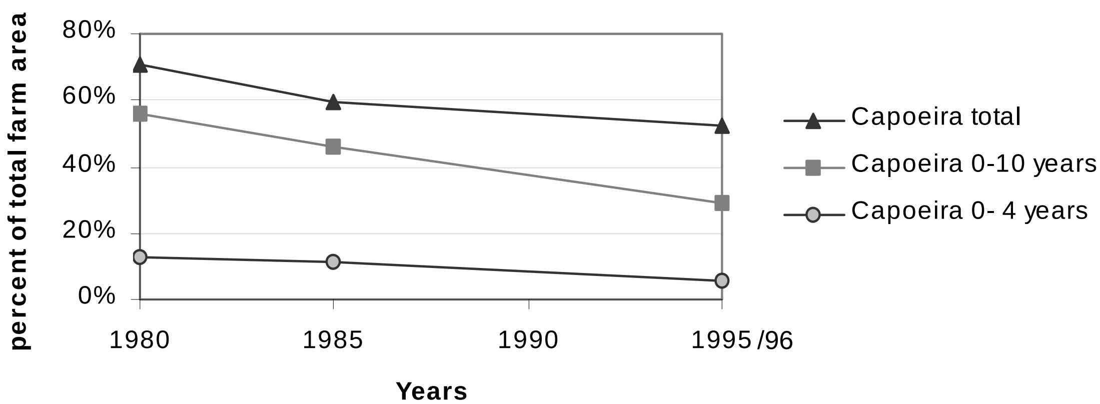



No data available for Capoeira < 4 years in 1970

Source: IBGE 1979, IBGE 1983, IBGE 1991, IBGE 1998

[8] According to IBDF (1982) 95% of the vegetation cover of Igarapé-Acu, one of the oldest municipalities in the Bragantina has been changed, cited in WITHELM (1993).

**Figure 3. C*apoeira* area (in percent of farm area) in the three municipalities Capanema, Castanhal and Igarapé-Açu, 1980-1995/96**




Source: 1980-1995, **IBGE** 1983, **IBGE** 1991, **IBGE** 1998

## Characteristic of the Smallholder Land-use System

One of the major characteristics of the smallholder land-use system is the transformation of fallow vegetation into aches by slash-burning, which serve as a nutrient source for the subsequent crop. Farmers clear fallow areas of about 2 hectares annually and cultivate annual crops or establish perennials or pastures. In the case of annual crops land is used for one cropping period (up to two years) only. The process of land clearing and cultivation is carried out manually. Fertilizer and pesticides are used for perennials and beans only.

Characteristics for smallholders' land-use can be derived from a recent socio-economic survey (November 2002) of 271 randomly selected smallholder households in the Bragantina region[9]. The findings indicate that an average smallholding has 21 hectares with 3.8 hectares of cropland out of which 13% is utilized for perennials (pepper or passion fruit). The share of fallow is recorded with 54% on average, which corresponds to the census data of 1995/96 (see Figure 3), but if correct would leave substantial farm areas for settlements, farm roads, streams, etc. Out of the total labor force 25% is hired by 16% of farmers. Forty-eight percent of households are involved in off-farm activities, which comprise both regular and temporary work, the latter consisting mainly of seasonal labor in agriculture. Sixty-five percent of smallholders are land owners.

[9] The survey is part of an ongoing project on "Smallholders in the Eastern Amazon: Interaction between Ecosystem and Social System in the Utilization and Use of Tropical Forest" carried out by the Center for Development Research, University of Bonn and the Federal University of Pará, Belém. The current status of data processing and analysis only allows for limited analysis at this stage.

## SAFETY NET FUNCTIONS

This chapter describes various safety net functions of the fallow component of the smallholder land-use system. It thereby distinguishes between direct and indirect functions, that derive from (1) the consumption and sale of extracted *capoeira* products and (2) the biophysical processes and ecosystem functions, which maintain the agricultural productivity. The holistic and multidisciplinary view of these functions allows a better understanding of the system as a whole.

### Direct Safety Net Functions of the Fallow Component of the System

The fallow component of the smallholder land-use system directly provides farmers with a number of products that are consumed or sold (e. g. fruits, honey) or that serve as inputs into the processing of agricultural or household products (e. g. firewood or charcoal). Some products can be extracted when need arises either for home consumption or cash, or otherwise be reserved for further growth. This attribute constitutes a particular safety net function. Other products can only be harvested at certain times and, unless stored, surplus needs to be sold at prevailing market prices or, in case of absent markets, can only be given away. But even gifts have an important safety net component, because they strengthen dependencies within communities and foster mutual support in times of privation.

To some extent the extraction of products from fallow areas can be regarded in a similar view as extractivism from forests. Extractivism, which refers to the removal of forest products while forests are maintained, has received considerable recognition in the international discussion in the past two decades. This is mainly due to its perceived potential to maintain biodiversity, to sequester carbon, and to fulfill other important forest functions, while still allowing an economic utilization of forests. Controversy exists about the real potential of extractivism to generate economic alternatives, and some authors conclude that the favorable outlook on non-wood extraction may be over-optimistic (WUNDER, 1999).

#### Extracted Products

These considerations also apply to the extraction of products from secondary vegetation. The agricultural census holds municipality level information about quantities and value of forest products extracted. The data set covers 61 products including fruits and nuts, medical plants, fibers, different timber products, etc. The information is obtained from the total population of farmers within a municipality. It was mentioned already that in the Bragantina region primary forest has been reduced to an area of less than five percent. Thus, extracted forest products derive from privately owned secondary vegetation and from protected riparian areas, the so called *igapó* along rivers and streams.

Figure 4 shows values of extracted products for the Bragantina region as a percentage of net farm income (all farm sizes) for the two census years 1980 and 1995/96[10]. Total

[10] Agricultural censuses are conducted in five years intervals. No census was carried out in 1990. The 1985 census does not hold information on extracted forest products.

values for all products declined only slightly from 7.3 to 6.8% of net farm income over the period 1980 to 1995/96. But the composition of major products changed. While in 1980 firewood and charcoal dominated, in 1995/96 the extraction of fruits, particularly bacuri and açaí, gained increasing importance[11]. In general, these findings confirm our hypothesis that *capoeira* products have a potential safety net function. An additional income of about seven percent can help to overcome periods of insecurity. The fact that the extraction of the major products, firewood and its processing product charcoal, is not really time dependent, offers an additional security value to these potential income sources.

Further insight on the role of forest products and their contribution specifically to smallholders' livelihoods can be obtained from: (1) the socio-economic survey (November 2002) of 271 smallholders mentioned before and (2) a forestry study conducted in 1992 in the municipality of Igarapé-Açu (WITHELM 1993). The latter involves measurements of firewood yields from burned *capoeira* of different age and measurements of wood requirements for the production of charcoal and the processing cassava meal.

The 2002 survey (Tables 2 – 4) provides information about different products extracted from different sources (short and long fallow and *igapó*)**[12]**, their imputed market value, and the utilization of *capoeira* products. For simplification we categorized all products into eight groups (Table 2 to 4). Survey findings show that over the survey year a total of 71% of sample farmers extracted products from secondary vegetation. Charcoal and firewood are by far the most important products in terms of average imputed values (US$ 189 and 68, respectively) and in terms of smallholders involved in the extraction of these products. The imputed value corresponds to 6.2 and 2.2% of net farm income from charcoal and firewood respectively**[13]** for those farmers that are engaged in these activities. It has to be noted that charcoal is a processing product of firewood that involves a conversion rate of 1 : 3 $m^3$ of stacked wood, and a labor input of about 2 hours per 12.5 kg sac of charcoal (**WITHELM** 1993). On the basis of current farmgate prices (November 2002) for charcoal and firewood (US$ 1.06 per sac of charcoal and US$ 1.57 per $m^3$ of firewood) and a yield of 5 sac of charcoal per $m^3$ of firewood, a value-added of US$ 0. 37 per labor hour invested into the production of charcoal can be generated (versus US$ 0.31 for casual labor in agriculture). Since about 40% of smallholders produce charcoal and 11% of charcoal produced is sold (Table 4), charcoal production generates an average cash income of about US$ 8 per annum or less 0.2% of net farm income when considering all sample farmers (271). The larger proportion of wood used for charcoal production derives from long fallow (Table 3). Hence, the potential for continuation of

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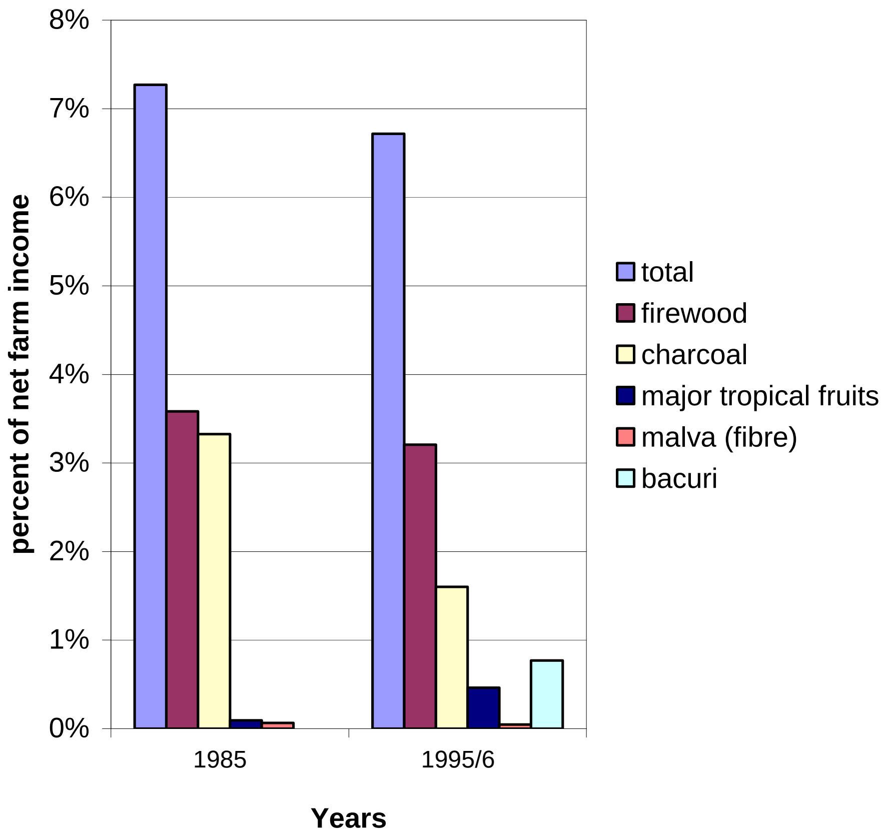
[11] Açaí fruit juice is a product that has greatly increased its market share, also in Southern Brazil, while in the Belém region bacuri and cupuaçu are increasingly consumed fruits (ANDERSEN et al., 2002).

[12] Conventionally short fallow defines areas of about less than four years while long fallow covers areas of more than four years. But, the actual biomass quantity usually differs depending on a number of factors that influence soil fertility and the regrowth potential of the *capoeira*. Since farmers in the survey were asked to distinguish between short and long fallow, we maintain this differentiation.

[13] Data of the Agricultural Census of 1995/96 were used and adjusted to derive net farm income.

this activity depends on the existence and maintenance of long fallow. To the extent that long fallow de facto shrinks over time, this benefit declines.

**Figure 4: Value of products extracted from secondary and riparian vegetation as percentage of net farm income. Sources:** IBGE **(1998),** IBGE **(1983)**




Major tropical fruits: açaí, cupuaçu, and pupunha

The second most important product extracted in terms of aggregated imputed market value is firewood, which is, however, primarily used for home consumption. Like charcoal, firewood mainly originates from long fallow, but with a larger proportion coming from short fallow. The market for firewood seems to be limited, hence only a small proportion (4%) is sold. This might be due to the fact that most rural people make use of their own resources, transportation costs for bulk products are high, and demand for firewood in urban centers decreases.

In addition, *capoeira* but also *igapó*, provide construction and fencing material, yet only sixteen and six percent of smallholders, respectively, extract these products, and less than three percent is sold. Particularly in the case of construction material, high quality timber deriving from distant primary forests is usually preferred. But roofing and wall construction material from the *capoeira* is still used for traditional wood and mud houses.

Food and the remaining other products are extracted by few farmers only. Apart from material for small tools most of these products derive mainly from long fallow or, in the case of larger logs and to some extent fruits, from *igapó*. Except honey, almost all of these products are solely used for home consumption or as gifts.

In an attempt to depict a trend in terms of the contribution of extracted products to net farm income, we compared the survey data 2002 with the census data from 1980 and 1995/96 (Figure 4). To obtain a comparable value we divide the total value of extracted products from survey data by the total number of sample farmers (271). In 1980 and 1995/96 the value of extracted products as a percentage of net farm income is 7.3 and 6.8% respectively, survey data (and adapted census data for income) show that it declines to only 2.5% in 2002. If such a decline really happened it would imply that capoeira products are playing a decreasing role as potential safety nets. A number of factors could be responsible, for example the negative trend in available fallow area (see Figure 2 and 3) continued, hence less fallow to extract from is available. Or, if we think of capoeira products in terms of a safety net, it could mean that alternative safety nets developed. This actually seems to be the case in terms of health insurance and old age pensions. Survey findings show that today a large proportion of smallholders in the Bragantina are health insured and entitled to pensions through syndicates (even for health) and private schemes.

**Table 2. Imputed values for extracted products for the one year period 2001/2002 (US$)**

| Products | Number of Extracting Smallholders | Mean[1] | Standard Deviation |
|---|---|---|---|
| Charcoal | 109 | 189.33 | 535.46 |
| Firewood | 134 | 68.46 | 249.45 |
| Fencing material | 17 | 91.48 | 127.74 |
| Construction material for houses | 43 | 24.72 | 44.42 |
| Honey | 5 | 90.83 | 94.15 |
| Fruits | 11 | 31.97 | 60.59 |
| Wood for heavy constructions (bridges) | 8 | 33.03 | 43.10 |
| Material for small implements or tools | 3 | 5.51 | 7.28 |
| All Products | 271 [2] | 82.33 | 338.67 |

[1] Mean of all smallholder who extract the respective product

[2] All sample farmers not only the 70% of farmers that extract forest products.

Source: ZEF Bragantina Baseline Survey, SHIFT-Socioeconomia, 2002

**Table 3. Origin of extracted products, as percentage of total value of extracted products**

| Products | Short Fallow | Long Fallow | Both Types of Fallow | *Igapó*[1] | All Locations |
|---|---|---|---|---|---|
| Charcoal | 33. 3 | 48.2 | 18.4 | 0 | 100 |
| Firewood | 39.9 | 31.5 | 27.1 | 1.5 | 100 |
| Fencing material | 0. 2 | 91. 7 | 8. 1 | 0 | 100 |
| Construction material for houses | 8. 1 | 55. 9 | 30. 3 | 5. 7 | 100 |
| Honey | 24. 2 | 75. 8 | 0 | 0 | 100 |
| Fruits | 8. 1 | 67. 8 | 2. 2 | 21. 9 | 100 |
| Wood for heavy constructions (bridges) | 5. 2 | 44. 8 | 0 | 50. 0 | 100 |
| Material for small implements or tools | 83. 4 | 16. 6 | 0 | 0 | 100 |

[1] Protected riparian areas

**Table 4. Utilization of extracted products, as percentage of total value of extracted product**

| Products | Sale | Consumption | Gift | All |
|---|---|---|---|---|
| Charcoal | 11. 0 | 65. 1 | 23. 9 | 100 |
| Firewood | 3. 7 | 93. 3 | 3. 0 | 100 |
| Fencing material | 2. 7 | 97. 3 | 0 | 100 |
| Construction material for houses | 1. 9 | 87. 8 | 10. 3 | 100 |
| Honey | 60. 6 | 39. 4 | 0 | 100 |
| Fruits | 3. 1 | 35. 8 | 61. 1 | 100 |
| Wood for heavy constructions (bridges) | 0 | 100. 0 | 0 | 100 |
| Material for small implements or tools | 0 | 83. 3 | 16. 7 | 100 |

## Indirect Safety Net Functions of the Fallow Component of the System

Safety net functions of forest fallows include not only products that are directly beneficial to farmers but also goods and particularly services that are indirectly beneficial. These services derive from properties and processes of the fallow system and represent assets that commonly have no market value. Examples for services of the forest fallow are the maintenance of the system's productivity (soil organic matter, nutrient accumulation, erosion control), the provision of habitat and shelter for a multitude of beneficial animals (game, pollinators, antagonists of pests, decomposers) or the contribution to climate regulation (water conservation, carbon sequestration). Moreover, forest fallows contribute to species diversity in agricultural landscapes. Although most services lack clearly defined economic values, they are crucial for the functioning and, hence, the success of the farming system.

**Forest regeneration and biodiversity**

In forest-based fallow systems, adapted regeneration mechanisms ensure the continuity of trees and shrubs and, thus, of vital forest vegetation. Cropping and fallow periods cannot be considered independently from each other, as the agricultural practices applied during the cropping period affect directly or indirectly structure and species diversity of the subsequent fallow vegetation. In particular, land preparation including the slash-and-burn technique and, more importantly, plowing and harrowing before planting, affect the species composition of the forest fallow.

Investigations in the Bragantina region show that due to management and land-use intensity, the regeneration of trees and shrubs from seeds does not play a major role in fallow land (CLAUSING 1994, JACOBI 1997). This can be attributed to the fact that most of the woody species do not reach the necessary maturity to produce fruits and seeds during short fallow periods and if any seeds are present, seedlings have little chance of surviving the weeding procedures during the cropping period or the land preparation process. Practically all tree and shrub species regenerate vegetatively by resprouting from their root system that survived the cropping period. As a consequence, tillage as a land preparation means has adverse effects on the regrowth of forest fallows once the cropping period is over. Tillage destroys the root system in the topsoil, impairing resprouting of trees and shrubs and reducing their biomass accumulation. In particular grasses invade these areas. In fallowed areas that had been cultivated traditionally[14] fallow vegetation continues to be dominated by woody species, even after several land-use cycles. Tillage, in contrast, leads to the structural and floristic degradation of forest fallows (Table 5).

On farmland with repeated land-use cycles over decades, fallow vegetation establishes in which the plant species had been subjected to selection pressure in favor of vegetative resprouting potential. The regeneration potential of those forest fallows fulfills its safety net function in combination with traditional agricultural practices or modern management techniques that take care of the root system.

The maintenance of a high diversity of woody species does not only allow a multiple use of the forest fallow but also implies the occurrence of tree species which have the potential to form high forests.

**Table 5. Aboveground biomass (t $ha^{-1}$) of fallow vegetation in areas with traditional and mechanized land preparation**

| | No tillage | | Plowing and harrowing | |
|---|---|---|---|---|
| | **woody** | **herbaceous** | **woody** | **Herbaceous** |
| 2-year fallow | 10. 1 A | 4. 4 a | 4. 3 B* | 6. 2 a* |
| 5-year fallow | 22. 8 A | | 15. 0 B + | |

Different capital or small letters within rows indicate statistically significant differences between means (Tukey test; * p < 0. 1, + p = 0. 223)

[14] Manual slashing of the fallow vegetation, slash burning, no tillage, cropping period of 1-2 years.

Due to the selective effects that land-use has on species composition, the species diversity of a forest fallow is *a priori* a floristic specialty and can be classified as an anthropogenic plant community. Although species numbers are lower in fallow vegetation than in primary forests, vegetation surveys in 92 young to medium-aged fallow areas (1 - 10-year-old) revealed a total of 673 species belonging to 97 plant families (BAAR 1997). Out of these, 316 species were trees and shrubs. In old secondary forests (>20-year-old), we found 51 tree species, considering only tree individuals with a diameter >5cm.

To assess the forest formation capacity of young fallow vegetation, 67 representative tree species occurring in young fallows were classified according to their potential height at maturity. The analysis revealed that 28% of the species can be classified as small trees (<8m), 21% as trees of medium height (8-20m) and 51% as tall trees (>20m). Forty-seven of these tree species, however, could be found in less than 30% of the fallow areas only.

Although the frequency of many individual species is relatively low, it can be stated that the diversity of tree and shrub species still maintains the forest-formation capacity of the fallow vegetation in the study region and, thus, has a stabilizing effect on the productivity of the fallow system due to the biomass accumulation and nutrient storage capacity of woody species. The safety net function of species richness and diversity is extended by the fact that a considerable number of tree and shrub species provide, for example, construction material or fodder: 58% of 144 (WITHELM 1993) and 16% of 192 studied species (HOHNWALD 2002) have been identified as useful construction wood and fodder plants for cattle, respectively. Furthermore, it has been observed in young fallow vegetation that the flowers of 59 plant species (including 38 woody species) are visited by bees (mainly honey bee) to collect nectar and pollen (Giorgio Venturieri, unpublished data). This finding confirms farmers' information that young fallow vegetation occasionally plays a role for honey production.

**Nutrient and organic matter supply**

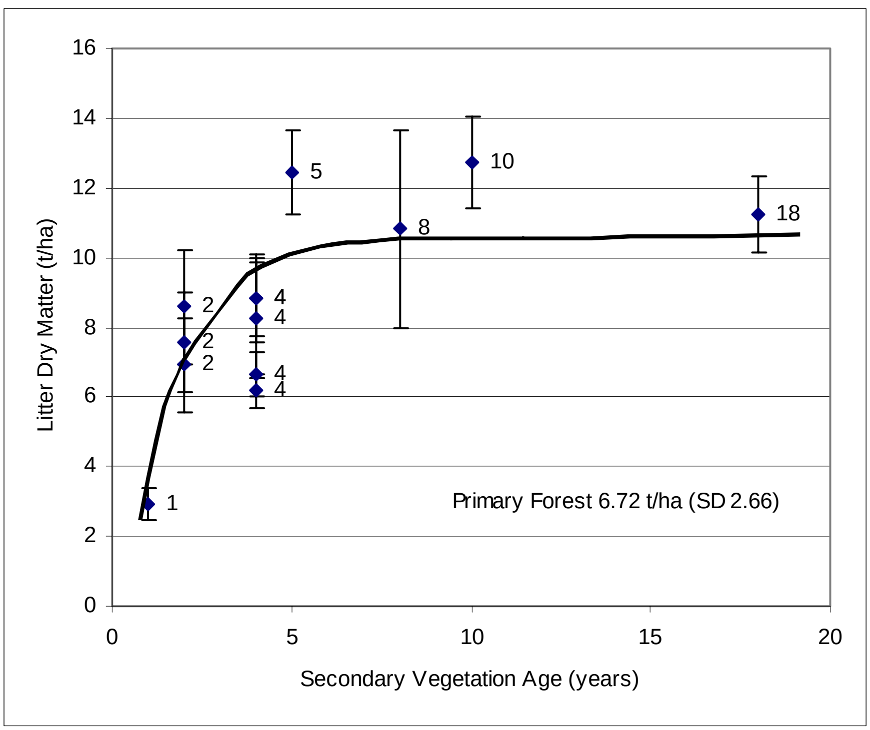
Nutrient and organic matter supply in the traditional fallow system are secured, as long as fallow periods are long enough and the natural processes of atmospheric deposition, deep soil recycling, and biological fixation are guaranteed. Except for the atmospheric deposition, all processes are highly dependent on the vitality of the fallow vegetation. The potential lies in its structural mix of trees, shrubs, vines and herbs and in its species diversity containing for example nitrogen fixing species. Their safety net function has to buffer the losses caused by burning, leaching and harvest removal.

The nutrient pump out of deep soil layers is to be pointed out as the most important mechanism. Many of the fallow vegetation roots reach to a depth of 6 m (SOMMER et al. 2000), from where they recover considerable amounts of nutrients which they return to the topsoil through the litter. According to SOMMER (2000), the capacity of the fallow vegetation for deep soil-water use and thus nutrient uptake exceeds that of cultivated crops 3 to 4 times. Nutrient leaching beyond the crop rooting depth of 0. 9 m and up to a maximum depth of 3 m was 32 kg $ha^{-1}$ of total nitrogen, 1.7 kg $ha^{-1}$ of phosphorus, 7 kg $ha^{-1}$ of potassium, 53 kg $ha^{-1}$ of calcium, 14 kg $ha^{-1}$ of magnesium, 7 kg $ha^{-1}$ of sulfur (SOMMER 2000). Since crop roots do not reach much beyond 0.9 m these nutrients can only be recycled by the fallow vegetation. Considering nitrogen only this would represent roughly one sac of fertilizer $ha^{-1}$ which costs about R$ 45 at the (August 2002), an equivalent of US$ 21 $ha^{-1}$ or US$ 84 for the commonly planted 4 hectare per annum.

These findings are supported by the analysis of litter stocks that are found on the soil surface under fallow vegetation. After turning into fallow the amount of litter soon reaches that of a primary forest (Figure 5) and a steady state equilibrium after about 10 years. Litter decomposes on the soil, thus releasing nutrients into the topsoil from where they become available to the crops of the next cropping period. This contributes to keep the traditional shifting cultivation system functional, even at low or no inputs, provided that fallow lengths allow litter accumulation to be sufficient before cropping is repeated.

**Figure 5. Litter stocks at the end of the rainy season (September) of secondary vegetation of different ages and of primary forest.**

(Whiskers denote standard deviations, regression curve denotes trend)




Another safety net function of the fallow system, deriving also from litter, is the maintenance of soil organic matter. It guarantees active soil biology and sound soil structure, which form the basic precondition for soil fertility. Litter suppresses herbaceous weeds by building a mechanical barrier particularly against seed borne weeds. At later successional stages, this effect is supported by the shade of the dense fallow vegetation. However, since fallow periods become shorter these safety net functions of the traditional system are endangered. Less litter is being produced and decomposed on the ground. In addition to that the nutrients contained in it derive from superficial soil layers, because the young fallow vegetation only forms a shallow rooting system. Therefore, nutrients of deeper soil layers can easily be leached. More inputs in terms of labor (weeding) and nutrients (fertilization) are the consequence. If the removal of higher amounts of organic matter and nutrients[15] by burning at land preparation could be avoided, the negative effects of the short fallow periods could be counteracted significantly.

### Carbon Sink

The carbon sink function can be seen as a typical service function of forest fallows. Although carbon is only temporarily immobilized in fallow vegetation, adequate fallow management might raise the carbon stocks of the fallow system to higher levels (DENICH et al. 2000). Such fallow management allows to shorten the land-use cycle and pays off agronomically due to increased land productivity. Additional income for the farmers might be generated by integrating the carbon sink function into environmental markets.

In a case study carried out in the Bragantina region, the aboveground carbon stocks of a 56-ha-smallfarm area were assessed with 390 t C or, on average 7 t C $ha^{-1}$ (TIPPMANN 2000). On the farmland, slash-and-burn agriculture with 1 to 2-year cropping periods alternating with fallow periods of several years predominated the land-use. Consequently, the fallow vegetation contributed 96% to the total carbon stocks, the remaining 4% were stored on the cropped fields. Other research findings show that aboveground carbon stocks of fallow vegetation lie between 3 and about 40 t $ha^{-1}$ (Denich et al 2000; Table 6).

**Table 6. Aboveground carbon stocks (t $ha^{-1}$) in live and dead biomass of different-aged fallow vegetation in NE Pará**

| Fallow vegetation | Carbon stock |
|---|---|
| 1-year-old | 3-5 |
| 4-year-old | 8-16 |
| 7-year-old | 18-33 |
| 10-year-old | 34-41 |

Source: modified after DENICH et al. 2000

Carbon sequestration by fallow vegetation is a function of species composition and time: the higher the abundance of trees and shrubs and the older the fallow is the higher are the carbon stocks. Moreover, the biophysical environment as well as agricultural practices affect the growth behavior and by that the biomass (= carbon) accumulation of fallow vegetation. once more we can refer to the adverse effects mechanized soil preparation has on the regeneration of vegetatively resprouting tree and shrub species. Tillage leads to fallow vegetation which is structurally very heterogeneous and consists of tree and shrub islands and grassy patches. The same can be observed if the cropping period is prolonged

[15] See Table 7, part “slash-and-burn”, line “burning”.

considerably beyond 2 years as in the case of semi-permanent crops, such as black pepper or passion fruit.

There are options to improve heterogeneous fallow vegetation structurally and stimulate carbon sequestration on smallholder land through fallow management, such as the introduction of fast-growing tree species into the fallow vegetation (BRIENZA 2000, DENICH et al. 2000). Within less than two years, fallow vegetation enriched with nitrogen-fixing leguminous trees accumulated carbon stocks which are comparable to 7-year-old unmanaged fallows. Empirical models show that in the long run enriched fallows can accumulate 2½-fold the aboveground carbon stock of the traditional fallow system. This management option, however, is coupled with additional costs in the form of planting material and labor. On the other hand, enrichment plantings allow to shorten the fallow period due to accelerated biomass and nutrient accumulation and, accordingly, the land-use factor increases improving the system's productivity in terms of protein and carbohydrate production by the factor 2 and 2½, respectively (DENICH et al. 2000).

Forest fallows offer economic prospects with regard to their carbon sink function. In addition to food production, carbon sequestration of forest-based land-use systems might be a future option for farmers to generate extra income through environmental markets. If trade in carbon sequestration services are realized, e. g. as part of the Clean Development Mechanism of the Kyoto Protocol, farmers could be asked to provide land and labor as a contribution to an environmental service. However, to ensure that fallow management works as part of the safety net functions, incentives and subsidies have to be guaranteed to farmers as compensations for the supply of land and labor (SMITH et al. 1997, SMITH and SCHERR 2002).

In order to get indications on potential returns to farmers we can assume that a fallow system with enrichment plantings has carbon stocks per hectare which are, on average, 7 t higher than the stocks of a traditional crop-fallow cycle (long-term means 13 and 6 t $ha^{-1}$, respectively; DENICH et al. 2000). For emission trade purposes commonly US$ 20 are calculated for each ton of additionally fixed carbon, compared to the respective baseline values. Therefore, with enrichment, an amount of US$ 140 per land-use cycle for each hectare could be expected. This amount is slightly above the costs of the enrichment planting (planting density 2500 trees per hectare), at a re-establishment after three land-use cycles a total of 12 years. For farmers, these payments could be incentives, in addition to the shortened fallow periods[16] and increased land productivity, which can lead to higher food production. At national level, the up-coming "Proambiente" program (see Section 4.3.2) offers subsidies for Amazonian farmers, which contribute to the conservation of nature and provide environmental services.

[16] With enrichment the cycle length is reduced to 4 years (2 years cropping and 2 years fallow) as compared to the traditional 6 years (2 years cropping and 4 years fallow), because under enrichment fast-growing trees accelerate biomass accumulation.

## Potential technical, policy and institutional innovations

### Technological innovations to improve the safety net functions

In the previous sections we saw how the system changes over time and what is being suggested to overcome the problem of degradation. To improve the safety net functions under advanced soil and vegetation degradation. We assert that litter can no more be the only source of organic matter and nutrients. In addition, the entire biomass of the fallow vegetation could be retained in the system instead of removing it by burning. In this context a chop-and-mulch technology is developed. Instead of burning the vegetation is chopped with a tractor-driven mobile bush chopper providing a layer of mulch. The latter adds to the litter and decomposes at the rate of halving the amount each year (KATO 1998). As Table 7 shows the amount of nutrients that can be maintained in the system are considerable. In the case of nitrogen they exceed the traditional fertilizer applications by a factor 4. A further advantage of chop-and-mulch is the flexibilization of the cropping calendar. Contrary to slash-and-burn, land preparation is not fixed to the dry season any more, which allows the farmer to react to changing market demands.

**Table 7. Comparative nutrient balance (kg ha$^{-1}$) of the entire crop-fallow cycle (3. 5 years of fallow and 2 years of cropping) after land preparation by slash-and-burn and chop-and-mulch**

| | Nitrogen | Phosphor | Potassium |
|---|---|---|---|
| **Slash-and-burn** | | | |
| Deposition, Biological Nitrogen Fixation | 26 | 4 | 12 |
| Fertilizer | 70 | 48 | 66 |
| Burning losses | -246 | -8 | -58 |
| Harvest, firewood, leaching losses | -143 | -23 | -89 |
| Balance | -293 | 21 | -69 |
| **Chop-and-mulch** | | | |
| Deposition, Biological Nitrogen Fixation | 26 | 4 | 12 |
| Fertilizer | 70 | 48 | 66 |
| Harvest, leaching losses | -122 | -23 | -86 |
| Balance | -26 | 29 | -8 |
| Gain from chop-and-mulch | 267 | 8 | 61 |

Source: adapted from SOMMER 2000

The initial safety net function of the nutrient pump is thus enhanced to an extent that can make up for the shortcomings of litter contribution due to shortening of fallow periods. This effect can be improved even more by boosting biomass production during the fallow period through enrichment (as discussed in section 4.2.3).

Enrichment planting experiments of fast-growing trees have shown that some of the enriched fallows produce greater amounts of biomass than the natural fallow and all are 160% to 200% higher in litter production, without significantly affecting floral diversity (WETZEL 1997). . Thus, organic matter and plant nutrient accumulation is improved once more. This holds if chop-and-mulch is applied at land preparation. If burning is applied the enrichment technology could easily turn into the contrary and mine the soil for nutrients.

In addition to improving the safety net functions in terms of organic matter and nutrients fallow enrichment also improves the safety net functions of secondary vegetation products as they were mentioned in Chapter 4. 1. 2. Some enrichment species produce fruits that present a desired nutritional supplement in the region, others produce wood that can be utilized as construction material or fuel wood.

### Policy and Institutional Innovations

Apart from technical innovations that smallholders can actively choose to adopt or to reject, farmers are confronted with policy and institutional innovations, which they can usually not influence. Brazil´s development debate is still dominated by the conflict between the two, often incompatible, objectives of economic development and environmental sustainability. Yet, in spite off efforts taken to jointly address the two objectives, implementation repeatedly failed as a result of lack of funding, inadequate institutional capacity and lack of cooperation and coordination. New approaches suggest to place environmental protection into the mainstream development agenda, by e. g. transferring some of the responsibilities to implement environmental policies to development-oriented agencies (PUMPIM DE OLIVEIRA 2002, BRANNSTROM 2001).

Earlier suggestions (BINSWANGER 1991) propose to remove distorting economic policies that create incentives for deforestation and to introduce a coherent system of land-use planning that sets aside more marginal lands in forest reserves and establishes biological reserves. An institutional innovation for these suggestions would be the introduction of an incentive system for enforcement agents (forest guards). BINSWANGER'S suggestions are based on the findings that general Brazilian tax policies in the 1980s (special tax incentives), rules of land allocation and agricultural credit systems all accelerated deforestation in the Amazon and negatively affected smallholders and the poor. The latter holds because tax exemptions on agricultural income and subsidized agricultural credit overvalued market prices for land, which made buying land impossible for smallholders.

Some of these negative effects resulted from previous policies can be observed in the Bragantina region. Table 1 suggests a decrease, though a slight decrease only, in the number of smallholders and a substantial decline in the *capoeira* area over the period 1980 to 1995. At the same time the number of fully commercial, intensively producing farms (poultry, black pepper or passion fruit) owned by corporations or new immigrants increased.

In order to counteract the negative developments, both on the social and the environmental front, the government now plans to introduce a new policy instrument to

Legal Amazonia. Proambiente is a program that particularly addresses smallholders and aims to remunerate them for environmental services. These services include the reduction of deforestation, and support for carbon sequestration, biodiversity and soil conservation (no burning), and the protection of the hydrological cycle. The program operates through subsidized credits, technical advice (by specifically trained and employed agents) and the certification of environmental services. The costs for the project (including a total of 37 500 farmers) are estimated at R$ 450 million (US$ 131 million) to be spent over 15 years. Funds will derive from existing credit funds (FNO[17] and other government credit programs). First estimations suggest that 15 years after the commencement of the project (assuming that each farmer reserves 15 hectares of land), 69 million tons of carbon will be sequestered, which reflects the current average annual industrial emissions of Brazil (**MATTOS** et al. 2001).

## CONCLUSIONS AND POLICY IMPLICATIONS

The forest-based fallow system practiced by smallholders in the Eastern Amazon is subjected to continuous changes. To guarantee livelihoods farmers adapt their land-use system over time responding to changing internal and external economic and environmental influences. This process affects various safety net functions provided by the system, and farmer's perception of these safety net functions and their appreciation change accordingly. Environmental, agricultural and development policies should encourage research and extension and should support interested farmers to consider safety net functions when making land-use decisions.

1. Products extracted from secondary vegetation make on average a small contribution to smallholder livelihoods. This can, however, be more significant for individual farmers. The possibility to rely on returns from most extracted products at any time, offers a particular potential safety net function. Gifts made out of *capoeira* products, that apart from own consumption and sales are common, help to foster social relations and hence further safety. In addition, latest developments in terms of increasing demand for fruits (bacuri and açaí) or the up-coming interest for medical plants growing in short fallow are examples for possible future niche markets for *capoeira* products, which might not have been thought of yet. However, most products extracted derive from longer fallow, and if this ecosystem cannot be maintained, their contribution to livelihoods will further decline.

2. Due to a high diversity of tree and shrub species, the fallow vegetation of the Bragantina region still holds a potential for forest formation. This potential, however, only refers to forest structure and relevant functions of the forest ecosystem. As qualified tree species could not be found, prospects for future silvicultural use through the production of valuable timber are limited. On the other hand, when young, a considerable number of woody species serve as fodder plants for cattle or are nectar and pollen sources for bees.

[17] Fundo Constitucional de Financiamento de Norte

3. Provided fallow periods are long enough, nutrients and organic matter are sufficiently preserved in the fallow system in which they accumulate and recover soil fertility. When fallow periods shorten due to demographic pressure this “natural” function does not withstand and external inputs or completely new production systems become necessary. Yet, there is scope for new technologies to improve the system without having to replace it.

4. Forest-based land-use systems have a potential to provide environmental services. In particular, their forest component serves as a carbon sink, thus contributing to the removal of greenhouse gases from the atmosphere. Carbon sequestration of the fallow vegetation can be increased with appropriate fallow management techniques, such as enrichment plantings with fast growing tree species. The potential safety net function is being realized through the participation in national and international carbon markets, which give prospects for additional income to farmers.

5. The maintenance of a forest-based land-use system implies the repeated regrowth of woody fallow vegetation after cropping periods. In this regard, the safety net function of the fallow vegetation refers to the vegetative resprouting potential of tree and shrub species from their root system. Feasible ways to conserve species include no-tillage approaches during land preparation and cropping periods not longer than two years. The latter condition clearly conflicts with the production of perennial crops.

6. Through technological innovations soil and vegetation degradation can be stopped. Two technologies, mulching and fallow enrichment, can correct the weak points and recover the safety net functions by avoiding organic matter and nutrient loss at land preparation and by boosting fallow regrowth. They do this without changing the fallow system, hence by improving instead of replacing. Since smallholders are risk averse and tend to rely on existing safety nets, this could increase the chance of adoption.

7. Experiences show that previous policies and institutional arrangements fostered concentration, deforestation and shortening of fallow periods. New approaches aim to address smallholders’ need to generate income and external stakeholders’ concern to protect the environment. Whether the incentives offered are sufficient to allow farmers to provide environmental services remains to be seen.

The existing smallholder land-use system provides a number of direct and indirect safety net functions that individually regarded are small, but viewed in total, considerably secure smallholders’ livelihoods. Potential innovations, both technological and institutional innovations, which support the safety net functions of the system, are emerging. These innovations (e. g. the mulching technology and Proambiente) seem to be supplementary and try to address both the need for economic development as well as environmental sustainability.

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